24. The transmission line structure of claim 19, wherein said first and second beams in said first and second end sections are bendable by said first and second actuators into engagement with one another, whereby, said transmission line acts as an electrical switch.

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25. The transmission line structure of claim 19, wherein said transmission line comprises an adjustable phase shifter in which said first and second end sections of said transmission line comprise first and second capacitance tuning sections of said phase shifter whose capacitance is adjustable by altering the distance between said first and second beams. - -

REMARKS

The original claims are hereby canceled and replaced with new claims 10-25 that Applicants believe are patentable over the prior art of record, including the newly cited art submitted herewith in the accompanying Information Disclosure Statement. Reasons in support of Applicants' position are provided below.

Regarding the informalities noted in the Office Action, the examiner's suggestion to eliminate the word "type" when referring to the comb drive actuators has been accepted. In addition, the first and second end sections of the transmission lines are more clearly defined in new claims 10 and 19. As for the Examiner's objection to the drawings, Applicants respectfully submit that it is sufficient to show the comb-drive actuators in schematic block diagram form as they already are shown in FIG. 1 since these devices are well known in the art and do not in and of themselves comprise a significant feature of the invention. Accordingly, Applicants respectfully request that this objection be removed.

The present invention comprises a transmission line structure that can be employed in MEMS-based phase shifters and switches, for example. The invention employs suspended

transmission lines that are formed of spaced parallel electrically conductive beams that are laterally bendable toward one another using one or more microactuators. In the preferred embodiment, the beams are each formed from a single crystal silicon (SCS) core that is coated with metal, and the microactuators are comb-drive actuators. Lateral bending of the beams by the microactuators to vary the spacing between the beams in a controllable manner enables the structure to act as a continuously variable phase shifter because the characteristic impedance of any section of the transmission line is a function of the beam spacing in that section. The same arrangement can be employed to bend the beams of the transmission line into contact with one another, thereby allowing the beams to act as a switch.

The transmission line includes first and second end sections that are separated by a third, matching section which facilitates low insertion loss for a chosen frequency range by allowing any reflections from the end of the section to be 180 degrees out of phase from those from the beginning of the section, thereby causing significant cancellations of the reflected waves. The matching section is positioned at an angle to the first and second end sections. The microactuators are preferably connected to the beams near the corners formed between the first end section and the matching section and between the matching section and second end section so that the lateral spacing between the beams near the corners can be changed, and thereby the effective capacitance of the end sections can also be changed. Because the spacing between the lines is extremely small, the structure shows very little reflection from the discontinuities up to high frequencies. Thus, varying the distance and therefore capacitance between the beams near the corners induces variable phase shifts while the matching section functions to cancel the reflections from the first and the second end sections.

The foregoing design with the matching section disposed at an angle relative to the first and second end sections is advantageous for a number of reasons. A standard fixed-fixed straight beam transmission line, which normally comprises a typical transmission line system, is quite difficult to bend in the middle to any appreciable extent. This is because a fixed-fixed beam has a very high nonlinear spring constant perpendicular to its length since both of its end boundary conditions are fixed and the entire spring must thus stretch axially for large displacements. However, if a kink is inserted in the middle of the structure, the spring constant can be lowered significantly, especially for large displacements. The introduction of such a bend converts the single fixed-fixed beam into two cantilever beams with a third beam in the center. This central beam must then bend to keep its angled connection with the two beams it is connecting. Thus, a shape with an angled section in the middle is much easier to displace than a simple fixed-fixed beam. In a conventional rectangular waveguide, enormous reflections would be cause by the angled bends that would preclude their use. However, experiments have shown that, due to the small scale of MEMs structures, the effect of the discontinuity presented by the angled bends is actually small enough that the structure can be employed in the phase shifter design without the reflections induced by it being prohibitive.

Since the beams can be displaced toward one another with much less energy, this means that at low voltages, MEMs microactuators can provide a large tuning range and therefore a large phase shift or switching function. These unique qualities of the design result in a high-performance continuous microwave phase shifter or switch on silicon that is inherently low-cost and has low power-consumption requirements. Further, in the preferred embodiment, the matching section is disposed at a right angle relative to the first and second end sections. This arrangement allows the matching section to maintain a constant spacing (characteristic

impedance) throughout the actuation process, which simplifies both design and analysis. In addition, many different such sections can be cascaded together to provide a system that has a more complicated behavior. For example a phase shifter with a broader frequency range could be obtained by cascading together several such subsection with different matching sections etc.

With reference now to the prior art rejections set forth in the Office Action, claims 1 and 3-9 stand rejected under 35 U.S.C. 102 as being anticipated by U.S. Patent No. 5,839,062 to Nguyen et al., while claim 2 stands rejected under 35 U.S.C. 103 over Nguyen et al. in view of U.S. Patent No. 6,265,806 to Suzuki. Claims 1, 6 and 9 also stand rejected under 35 U.S.C. 102 as being anticipated by U.S. Patent No. 6,020,564 to Wang et al. Applicants respectfully submit that the replacement of claims 1-9 with new claims 10-25 renders these rejections moot for the following reasons.

From only a cursory review of Nguyen et al. and Wang et al., it is clear that neither of these references disclosed or suggests the transmission line structure recited in independent claims 10 and 19 in which first and second parallel beams each have first and second bends therein defining a matching section, and at least one actuator is provided to bend at least one of the beams toward the other to alter the electrical characteristics of the transmission line. As discussed previously, the angled matching section is a key feature of the invention that allows the bending of the transmission line beams toward one another with minimal power. Nguyen et al. simply disclose an electromechanical resonator whose normal vibrational modes serve to mix and filter the input signals. By no means, do Nguyen et al. disclose the structural arrangement recited in either claim 10 or claim 19. This is also the case as to Wang et al. that disclose a typical prior art switch structure. Although beams are cause to bend in Wang et al., it is clear that this reference also fails to disclose or suggest the specific structural arrangement recited in

claims 10 or 19. Further, the dependent claims that recite the switch function, claims 17 and 24, recite that the first and second beams of the transmission lined are bendable into engagement with each other to serve a switch function. Wang et al. clearly fail to disclose this specific arrangement and merely disclose a typical switch arrangement in which two electrodes come into contract with one another.

Although the newly cited reference to Ayon et al. discloses the general concept of using actuators to change the distance between transmission lines to change their electrical characteristics, this reference also neither discloses nor suggests a solution to the problem of bending the beams a significant amount in a fixed beam transmission line toward one another. Once again, the claimed invention solves the problem through provision of the angled matching section that greatly reduces the energy required to bend the beams toward and even into contact with one another.

In view of the foregoing, Applicants respectfully submit that new claims 10-25 are patentable and allowable over the card prior art and that the application is now in condition for allowance. Accordingly, favorable reconsideration and allowance of the application is respectfully requested.

Respectfully submitted,

By: William A Blake

William A. Blake
Registration No. 30,548

JONES, TULLAR & COOPER, P.C.
P.O. Box 2266 Eads Station
Arlington, VA 22202
(703) 415-1500
Dated: December 23, 2002